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POTATO PRODUCTION IN CALIFORNIA

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FOREWORD

The Irish potato is one of our staple food crops, in the production of which California ranks as one of the leading states. As a quick maturing annual crop having high acre-value, it has played an important part in the development of districts now almost entirely given over to other lines of agriculture. However, as new land is becoming scarce, the industry at present is being centered within certain districts which have proved their especial adaptability to this crop. The increased prevalence of certain diseases, the necessity in many places of using commercial fertilizers in some form, the advantages to be gained through the selection of proper seed, the requirements of the markets as to variety, type, and quality of potatoes grown, and the increasing competition from other producing regions all make it necessary for the successful potato grower to have a considerable fund of knowledge of the potato plant, as well as of the culture of the crop. It is the purpose of this circular to discuss in detail certain phases of potato production, especially in the light of new information gained by scientific study in recent years.

PRESENT STATUS OF THE POTATO INDUSTRY IN CALIFORNIA

Table 1 shows the acreage, production, and car lot shipments of potatoes from California in recent years. Generally speaking, these have been years of heavy production in the country as a whole, and potatoes from other states have been shipped into California in increasingly large quantities. The rapid growth of the population of California cities has led to increased consumption of the crop by local markets, which partly explains the decrease in car lot shipments.

TABLE 1

ACREAGE, YIELD, AND CAR LOT SHIPMENTS OF IRISH POTATOES FROM CALIFORNIA¹

	Acreage	Yield, bushels	Car lot shipments ²
1920	95,000 ³	13,015,000	10,108
1921	74,000	10,360,000	8,252
1922	76,000	9,880,000	7,765
1923	52,000	7,800,000	5,690

¹ Weather, Crops, and Markets, 4:677, 1923.² For the crop year, May 15 to May 15. From Market News Service, U. S. D. A.³ Yearbook, U. S. D. A., 1920.

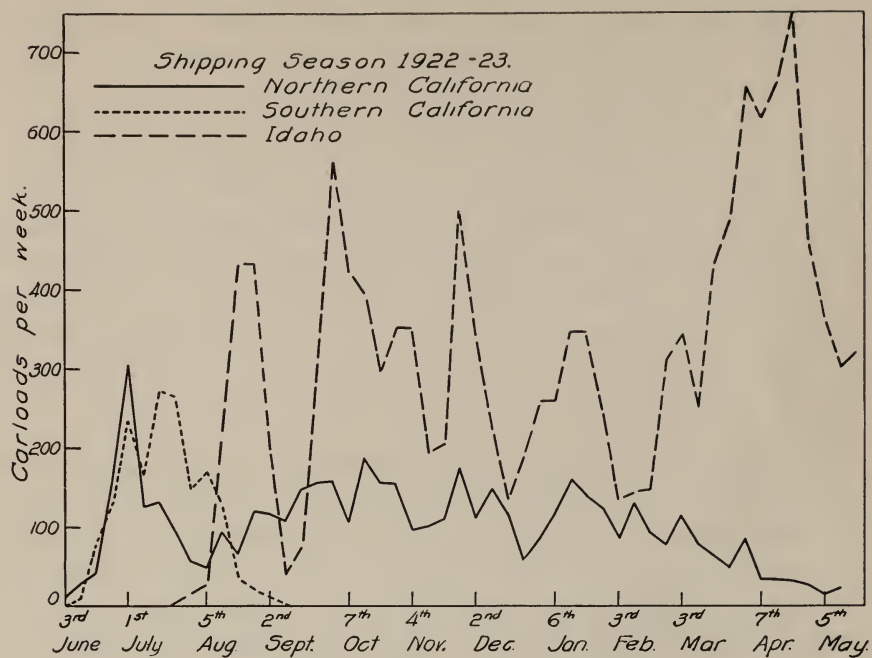


Fig. 1.—Car lot shipments of potatoes, by weeks, from Pacific Coast districts, for the season 1922-1923.

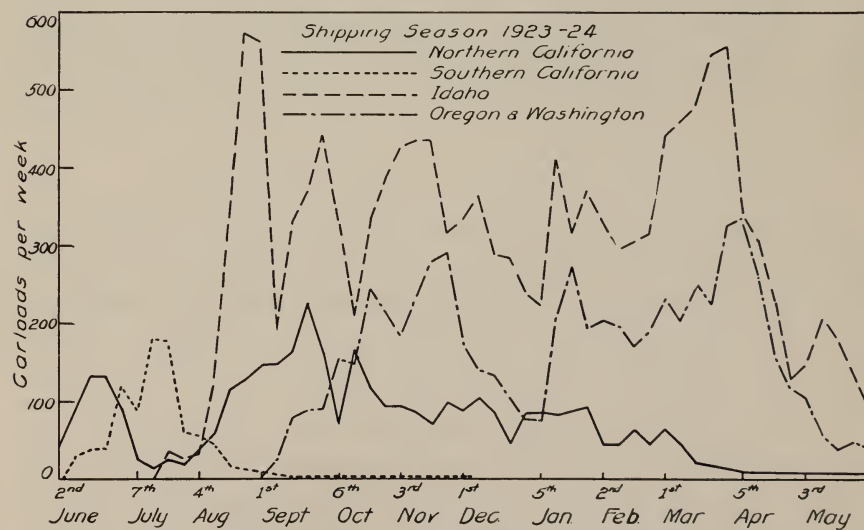


Fig. 2.—Car lot shipments of potatoes, by weeks, from Pacific Coast districts, for the season 1923-1924.

Competition with other states for outside markets, as well as for the home markets, has been the outstanding feature of potato marketing in recent years. This factor will have to be kept constantly in mind in future developments. The tendency is toward earlier crops and earlier shipping of the California crop, thus avoiding to some extent direct competition with the main crop in the Northwest. To show the relation of California shipping seasons to those of competing states, figures 1 and 2 have been constructed from data supplied by the Market News Service of the United States Department of Agriculture. These furnish us with a guide to the usual seasons of shipment and the volume of shipments from the principal potato districts on the Pacific coast—a region more or less independent of the rest of the country so far as production and consumption of potatoes are concerned.

Early in the season, during April and May, there is a considerable movement of “new potatoes” from the San Francisco district to California markets and to markets of the Northwest. This is followed early in June by a much heavier shipment of early potatoes from the lower San Joaquin Valley (Shafter district), which goes to local, Northwestern, and Southwestern markets. Shipments from this district cause the first “peak” in the movement of potatoes from northern California. Then in July come the peak shipments from the Los Angeles district, principally from the San Fernando and San Gabriel valleys. In August active movement begins from the Stockton district in northern California, and continues heavy throughout the fall months, gradually declining to a moderate, steady volume during the winter. A number of other, smaller districts in the northern part of the state harvest and ship their crop from October through the winter.

From March to the middle of August, the California potato districts have to compete with each other to some extent, but more particularly with the “old potatoes” of the previous year’s crop, still being shipped from the Northwestern states. The first is taken care of in some measure by the difference in season of shipment from the different California districts, the short periods of “peak shipment” from the several districts following each other in more or less regular order from April to August. Competition with “old potatoes” from the Northwest must, however, be considered during this period. While the home-grown new potatoes and the shipped-in old potatoes appeal more particularly to different classes of trade, still the supply of one kind has an influence on the price of the other. Hence, in

attempts to forecast probable market conditions for the California spring and summer crops, the size of the crop of the preceding year in the Northwest and the quantity being held over for spring shipments, are factors to be considered.

From the middle of August until the following spring, export of California potatoes to other states practically ceases, except for small quantities shipped to Arizona and New Mexico. Texas formerly furnished a market for considerable quantities during this period, but with the revival of potato production in Colorado and its expansion in Utah, these sections with a shorter haul now supply much of Texas' needs for late potatoes. During fall and winter, the California markets are being supplied to a large extent by the heavy shipments from Idaho, Washington, and Oregon. The Yakima Valley of Washington, with a combined freight rate of 36½ cents by rail and boat to San Francisco, and southwestern Idaho with a rate of 56½ cents, furnish the main competition for fall and winter markets. While California growers shipping at this season have an advantage in somewhat lower rates than these to the main markets, still it is not large. Another factor entering here is the market demand for certain types of potatoes. The bulk of the shipments from the Northwest are of the "Russet" or "Netted Gem" variety, which is generally considered an especially good baking potato and which the consuming public has become accustomed to use largely during the fall and winter. On the other hand, California stock available at this season is mostly of the long white type usually considered to excel other sorts as boiling potatoes. Potato growers have to consider the type of potato in demand by consumers at different seasons.

CALIFORNIA POTATO GROWING DISTRICTS

A number of more or less isolated districts have developed extensive potato production within the state, each district having certain advantages as to soil, climate, and shipping season. Cultural methods, varieties, time and method of marketing differ widely in different districts. The rather exacting requirements of the potato plant as to soil and climate render it unwise to attempt commercial potato production in new or untried districts until it has been determined that conditions are suitable for the crop, and that season of maturity and marketing facilities are such that the product can be disposed of advantageously. Arranged in approximate order of shipping season, the principal districts are discussed briefly below.

San Diego County.—Several small districts in this county specialize in winter potato production. Seed harvested in August is planted in November, and the crop is harvested from February to April. British Queen has been the principal variety used because of its vigorous growth during the cool winter months. White Rose is also being used. The crop of this district is usually dug when only partly developed. The product is marketed in lugs and shipped by express or by truck to California markets. The use of earlier varieties, such as Irish Cobbler, Idaho Rural, and Bliss Triumph, might increase the yields obtained in this district.



Fig. 3.—Thrifty field of White Rose potatoes at Shafter, California, planted with certified seed at the rate of 16 sacks per acre. Note 2-inch pipes in head ditch for irrigation. Yield 195 sacks per acre.

Colma, San Francisco County.—The mild winters on the hillsides near the ocean permit the culture of winter potatoes. The Garnet Chili is the standard variety, seed being grown in Oregon and planted at Colma from November to February. The later plantings are on the lower, more level fields, which produce a winter crop of cauliflower before being planted with potatoes. The crop matures from the first of April to the first of July. The earlier harvests are of partly grown tubers that go to local and nearby markets in lugs, but as the crop becomes more mature, carlot shipments are made to more distant regions, especially to the Northwest. The installation of vacuum fumigation plants should aid in expanding the shipments to states having tuber-moth quarantines. The Garnet now used is a late variety and perhaps could well be supplemented with similar varieties that mature in a shorter time.

Shafter, Kern County.—This district has developed rapidly in recent years. The sandy soils and warm spring weather are favorable for the production of standard varieties for shipment in early summer. White Rose is the variety used, seed being planted in February and maturing in June or July. Late plantings are likely to be injured by heat or by tuber-moth. Shipments are mostly sacked, in car lots, though there are some extra early shipments in lug boxes.

Los Angeles County.—The San Fernando and San Gabriel valleys are the main districts. White Rose is the variety generally grown in this county. The seed is grown locally the preceding fall and planted from February to April. Certain favored localities are able



Fig. 4.—Potatoes as an intercrop in a two-year-old vineyard at Shafter.

to plant in December and these “winter potatoes” are harvested in the spring and marketed in lugs. Car lot shipments of sacked stock begin about July 15 and continue for about six weeks. Local markets consume most of the crop. A second or fall crop is also grown, planted in late July or early August, and harvested during the early winter. Much of the fall crop is used for seed. Maturing in the cool fall weather makes these potatoes equivalent for seed purposes to those “northern grown,” provided ample moisture is available for their development during the latter part of the growing season.

Sacramento-San Joaquin Delta.—The newly reclaimed peat or tule land of this section has been the most important potato district in California. Exploitation of the raw land by Oriental growers has led to a rapid decline in yields. The indications are that intelligent methods of production will restore and maintain potato production permanently in this section. The chief problems are control of diseases and use of fertilizers according to modern scientific prin-

ciples. Though the Burbank variety was formerly grown it is rapidly being replaced by the "Pride Burbank," also known as "Wisconsin." Planting commences in March and continues until June. Harvesting begins in July and continues until January. The tendency now is toward earlier planting and shipping to avoid competition with the Northwest. Large yields are possible on the peat and muck soils of this district. The quality of the potatoes grown in this region, known on the markets as "Rivers," is quite variable, and seems to depend largely on the skill with which the water supply is handled.



Fig. 5.—Potatoes as an intercrop in eight-year-old walnut grove.

Pajaro Valley and Salinas Valley.—These are the oldest potato districts in California. The Burbank variety is grown mostly. The crops from these districts are late, shipments being in fall and early winter.

Marin and Sonoma Counties.—This is also an old potato district, centering around Sebastopol and Tomales. The crop is grown on rather rough land, without irrigation. Several varieties are grown but most of the commercial crop is of the British Queen variety, which is well adapted to this coastal district, but is not a popular type

on the large markets. Climatic conditions favor high quality, especially for seed purposes, but soil conditions appear to be responsible for the rather low yield.

Other Districts.—There are several other smaller districts. In Humboldt County the British Queen variety is grown for shipment. Modoc, Lassen, and Inyo counties on the east side of the Sierras grow a considerable quantity of the Netted Gem variety for shipment during fall and winter.

VARIETIES

Only a few really distinct varieties of potatoes are grown in California, though a confusing array of names is applied to them. Below are given in some detail the characteristics of the leading varieties. The best known name is recommended for varieties that seem to be identical. General adoption of such standard varietal names will help to avoid confusion in buying seed in future. The importance of knowing the characteristics of the leading varieties should be emphasized, if for no other reason than that of recognizing and discarding varietal mixtures.

In order to gain more definite information as to the yielding possibilities and adaptability of various varieties to different sections in California, some variety tests were conducted during 1923 and 1924 by the Division of Truck Crops, at the University Farm at Davis, in coöperation with the Agricultural Extension Service¹ in Los Angeles County, and at Shafter in Kern County.² The results are presented in table 2. In so far as possible, two or more lots or strains of each variety were tested, and in such cases only the average yields for the group are given in the table. It is well recognized that varietal tests involving only one stock of a variety are unreliable, and may even be misleading.

Differences in time of maturity, type of potato, and adaptability to market requirements were observed that are fully as important as the gross yield produced by the different varieties. The difference between the early and midseason or late varieties is brought out by the early and late harvests of the tests at Davis. All varieties were planted February 24, and at the time of the first harvest, June 21, the Bliss Triumph, Earliest of All, Irish Cobbler, and Idaho Rural were practically mature, while in the other varieties tuber development was still in the early stages.

¹ Conducted by L. C. Holmes and F. H. Ernst, in coöperation with A. J. Mueller and Bert C. Bougher in 1923 and 1924, respectively.

² In coöperation with W. B. Camp, U. S. Dept. Agr. Cotton Expt. Station.

White Rose.—This is the main variety for southern California. It is a medium-early variety, being relatively earlier than the Burbank or British Queen, but later than Irish Cobbler or Idaho Rural. The plants are of medium size, erect, with many well developed lateral branches from the main stem, a feature which gives the plant a spreading appearance late in the season. The stems are bright green in color. The flowers are white. The tubers are white, have few eyes, and are rather long and flat, being rounded at the apical end but often pointed at the stem end. The White Rose can be distinguished from the Burbank in that the tuber is flatter and wider in the central part, while that of the Burbank is usually more cylindrical and about the same width throughout its length. Soil conditions, however, have a great deal to do with shape and smoothness of any tuber. When grown under favorable soil and climatic conditions, the White Rose has smooth evenly shaped tubers of fancy appearance for market. Experiments indicate that the natural rest period of the tubers of this variety is shorter than in most other sorts, making it well adapted to the practice of growing two crops a year.

TABLE 2

YIELDS PRODUCED BY VARIOUS VARIETIES OF POTATCES AN SPRING CROP TRIALS

Variety	Davis-1924				Van Nuys-1923		Alhambra-1924		Shafter-1924	
	Dug June 21		Dug. Aug. 1		Dug July 25		Dug July 18		Dug June —	
	No. of plots	Pounds per acre	No. of plots	Pounds per acre	No. of plots	Pounds per acre	No. of plots	Pounds per acre	No. of plots	Pounds per acre
Bliss Triumph.....	1	13,850	3	14,500						
Earliest of All.....	5	13,550					1	12,022		
Irish Cobbler.....	2	13,000	3	16,150	1	34,825	1	12,320		
Idaho Rural.....	2	11,825			1	30,550			1	17,714
White Rose ¹	19	9,820	1	23,750	10	23,000	3	10,541	4	12,713
American Wonder ²	5	9,330	3	14,720	2	23,880	1	4,700	1	11,158
Early Red Rose.....	2	7,900	1	11,450				15,611		
Green Mountain.....	1	7,600	4	18,525	3	32,854	1			
King ³	1	6,850	2	16,800	1	34,100				
Burbank.....	2	5,415	9	14,700	2	25,750			1	12,333
Garnet Chili.....	1	1,470	2	10,390	2	17,940				
Russet Burbank ⁴			6	15,640	3	24,315	1	5,530		
British Queen.....			8	11,504	1	27,175				
Rural New Yorker.....			1	19,600	1	21,000	1	1,334		
Brown Beauty.....			1	11,350						

¹ California type—includes Great Divide, Wisconsin Pride, American Giant.² Some lots received under this name were the same as Burbank.³ Includes Candian Queen and Chicago Market.⁴ Includes Netted Gem.

The "Great Divide" grown in southern California appears to be identical with the White Rose, and the variety now being grown so extensively in the Sacramento-San Joaquin district under the names Pride Burbank, Wisconsin, Wisconsin Pride, and Late Pride, likewise seems to be nearly or quite the same as the White Rose. The Late Pride is an old established variety in Wisconsin and Minnesota, whence many carloads of seed are shipped to California and grown under the names mentioned above. The name "White Rose" probably is of later origin than Late Pride, but the former name has become so well established in California that it is thought best to retain it as the name for the entire group as grown in this state. The variety, "American Giant," much grown in New Jersey, also seems to be identical with this group. However, the White Rose grown in the East is distinctly different from the variety grown under that name in California.

Burbank.—This was long the standard variety in the Delta district, but it is now giving way to the White Rose type. It is still grown extensively in some of the coastal and interior districts of northern California. Three strains are grown, Low Top Burbank, Pride of Multnomah, and High Top Burbank. The tubers of these strains are alike, but the tops increase in size in the order in which they have been mentioned. The plants are more erect and have larger, coarser leaves than the White Rose. The flowers are white, the cyme is purplish—another distinction from the White Rose, in which the cyme is light green. The tubers are long, slightly flattened or cylindrical, slightly pointed at both apical and basal ends, and have a large number of eyes. It is a late variety.

Russet Burbank.—This variety is more generally known as Netted Gem, or Idaho Russet, since such large quantities are shipped from Idaho. It is little grown in California except at the higher elevations east of the Sierras, though it grows very well in other sections. It has been found to produce especially well in the peat soils of the Delta district though it has not yet been grown there on a large scale. The season is late. The plants and tubers resemble Burbanks, except that the tubers are covered with a dense, brownish corky netting. This netting is less marked when the potatoes are grown in peat or muck soils. A serious defect in both the Netted Gem and the white varieties of Burbanks, is the tendency to produce a knobby second growth on the tubers when raised on heavy uncongenial soils, or with an irregular moisture supply.

Garnet Chili.—This is probably the oldest variety now grown in America. In California it is grown in the Colma district near San Francisco. In time of maturity it is relatively a late variety, but when planted in the fall it produces a fair crop in early spring—hence so far as market is concerned it is considered an early potato. The plants are tall, erect, rather spindling in habit of growth. The stems are purplish, and the flowers are also purple. The tubers are slightly elongated or nearly round, and tend to have deeply sunken eyes. The skin is smooth and of a light pink color early in the season, but as maturity approaches, the skin becomes rougher and darker in color. The Garnet Chili, which is the only pink skinned variety of any importance in California, is grown for the early market. Whether or not it has any peculiar advantage as a winter grower in the coastal frost-free districts has not been determined. It is not recommended for trial elsewhere.

British Queen.—This is a standard variety for coastal districts from San Francisco north to Washington. It is more strictly limited by its climatic requirements than most other varieties. Only in a constantly cool humid climate will the plant and tubers develop normally. In the interior valleys and in the warmer parts of the south, tubers do not develop satisfactorily. Under conditions prevailing in such localities white sprouts appear from the apical end of the young tubers, and may develop laterally in the soil for some distance, stopping at intervals to form other small tubers or proceeding to the surface of the soil to form vegetative shoots. This abnormal development of tubers results in a crop of little market value. Under irrigated conditions in warm sections, the plants may grow rapidly all season with the formation of very few marketable potatoes. On the other hand, where there is a long, cool growing season this variety thrives and produces well. The plant is a relatively vigorous grower, tall, erect, dark green. The blossoms are usually profuse and are purple in color. By these purple flowers, mixture of British Queens in other varieties is often noticeable in all parts of the state. The tubers are slightly elongated, slightly flattened, smooth, with both stem and apical ends quite square and blocky.

The market demand for the British Queen is not great, and it usually sells at a much lower price than other standard varieties. This is said to be due to the tendency of the potatoes to cook to pieces when boiled, or to burst when baked. The culture of this variety is therefore not recommended, except for limited acreages in the regions where it is adapted. Growers, in sections where climatic

conditions prevent its maturing properly, have suffered much loss through the buying of seed of this variety under misleading names. Loss also regularly occurs through the admixture of a small percentage of this seed with that of other varieties, especially of those which mature and are dug before the British Queen has formed tubers of marketable size.

While this variety is of British origin, it is different from the English variety known as British Queen, but seems to be identical with the standard English variety Up-to-date. In the eastern states it is grown under various local names, and in Oregon it is known as Purple-flowered White Rose—a very misleading name to California growers accustomed to the California White Rose, a very different sort of potato.

Irish Cobbler.—The Irish Cobbler is the standard early variety of the East but is little grown in California. Tests show that it yields well both in northern and southern California, and matures two to three weeks before the White Rose. The tubers are white and nearly round, and the eyes are relatively deep, especially when grown on heavy soils. The plants are very dwarf and stocky, the blossoms are purple when first open, fading to white under intense sunlight. This variety is notably free from the tendency to produce knobby second growths or vegetative sprouts from the growing tubers.

Bliss Triumph.—The Bliss Triumph is the standard extra-early variety of the Middle West and Gulf States, but is little grown in California. It might well be grown in some places for early market as a substitute for the Garnet Chili. The tubers are nearly round, and are reddish in color. It yields well and matures early.

Idaho Rural.—This variety is also known as “Charles Downing” and seems to be similar to a variety called “Earliest of All.” The plants are relatively small, with finely divided leaves and white flowers. The tubers are somewhat elongated, flattened, and smooth. It has yielded well in northern and southern California, and while it is not exactly the type of tuber in demand on our markets, it should be further tested because of its earliness in maturity and its good yields. It may be expected to produce marketable potatoes in soils too heavy to produce most other varieties to advantage.

Late Rose.—This variety seems to be grown only in the Marin-Sonoma County district. It is an exceedingly late-maturing variety, having a very hardy, vigorous plant, bearing white flowers. The tubers are rough, inclined to be knobby, and because of their pink skin are not popular on most markets in their season, which is during the late fall and winter.

Green Mountain.—This is a standard main-crop variety of the Northeastern states, and is grown to a slight extent in California under such names as Gold Coin, Snow, and Carmen. The plants are large and vigorous; blossoms white, tubers white, elongated, slightly flattened, but rather rough in appearance. It will probably outyield most other sorts, but does not appear to be a particularly attractive market type when grown under irrigation.

SELECTION OF SEED

Much of the success of growing a crop of potatoes depends upon securing "good seed." Just what constitutes good seed potatoes is a difficult question to define, however. Few commercial potato growers produce their own seed, and perhaps in the majority of cases it is best that they do not. Therefore, the most of the potato acreage is planted with seed purchased from another grower, a dealer, or a seedsman. Seed so purchased is generally of unknown history and quality, except as to its appearance when received, and sometimes as to the reputation of the seed grower and the region where the seed was grown. Appearance of the seed is of practically no value in determining the quality of seed potatoes but the last two factors may mean a good deal. The production of high-grade seed potatoes is coming to be more and more a specialized business, and the need for some assurance as to quality has led to the development of "certified seed" production, a feature that will be discussed in detail at the end of this bulletin.

FACTORS AFFECTING SEED QUALITY

(1) *Appearance.*—While we are usually told to select tubers of a certain definite type, smooth, good sized, and attractive looking, none of these things have any connection with its producing qualities. The appearance and shape of tubers depends much on the soil and climate where grown. Experiments have shown that there is no correlation between show-stock qualities and ability to produce. Naturally, tubers are preferred that are free of knobby second growth, rots, and tuber-borne diseases, such as scab and Rhizoctonia.

(2) *Region of Production.*—There is a firmly rooted idea that seed from northern districts is more vigorous than that from more southern localities. Certainly it is true that potatoes grown under cool, humid climatic conditions are better than those grown in hot sections. Seed grown in southern California as a fall crop, in the

cool season of the year, may equal or surpass in producing quality that grown in the Northwest. While climate no doubt has some direct effect on the vigor of seed potatoes, it also has been found that high temperatures and low humidity mask the effect of certain diseases, especially mosaic, so that it is not possible to rogue out the diseased plants from the seed fields effectively where the temperatures are high, humidity low, and sunlight intense. These diseases are manifested most clearly in cooler, more humid sections. Thus the climatic factor may have much to do with the elimination of diseases, such as mosaic, which under severe climatic conditions weaken the plants without being readily visible. There is another factor in location, too. Some places are relatively free from aphids and other insects, and therefore enjoy a natural advantage in production of healthy seed. Where the potato aphid occurs in large numbers it is impossible to keep up disease-free seed stocks even when some roguing is done.

(3) *Irrigated vs. Dry Land Seed.*—No constant relation between this factor and seed quality has been established, except that in some sections plants affected by certain diseases, especially spindle tuber, that would eliminate themselves under dry-farming conditions, are enabled to survive under irrigation, thus producing more diseased stock. Probably this factor can be disregarded in California. Potatoes subjected to high temperature and lack of water just prior to harvest may result in inferior stock.

(4) *Maturity of Seed.*—It is generally believed that potatoes harvested in the immature condition are more vigorous for seed than potatoes that have fully matured in the ground before harvest, and there is much experimental data to justify this belief. Hence, crops intended for seed are often planted later than a market crop would be in the same section, so that vines will still be green when frosted in the late fall. There are probably several factors responsible for the advantages of immature seed.

(5) *Storage Conditions.*—These have a considerable effect on quality of seed. Potatoes kept in a warm place and allowed to develop long sprouts before planting will not produce good stands or vigorous plants. Much loss is due to decay of seed pieces in the ground, a fact which is often traceable to the wilted or shrivelled condition of the seed stock at the time it was planted. Storage rooms should be well ventilated, otherwise blackheart may occur. Where cold storage is used, a temperature of 36° to 40° F. is most favorable. Good ventilation is especially necessary to carry off surplus moisture, thus inhibiting both decay and sprouting of the potatoes, which are

likely to occur in moist storage houses. Bins provided with false bottoms and with bottom and top ventilation, have proved most satisfactory for bulk storage.

(6) *Infection with Diseases*.—Potatoes that show a large amount of scab or of *Rhizoctonia* on the surface should not be planted. These diseases in slight attacks are not serious if proper disinfection (in mercuric chlorid) is practiced. Potatoes showing internal discolorations, such as black-heart, internal browning, heat necrosis, or the brown ring below the skin associated with wilt diseases, should not be used. However, these diseases, which present more or less evidence of their presence on or in the seed tubers, have less effect on the quality of potatoes for seed, than the group of “virus” diseases.

This includes mosaic, curly dwarf, leaf roll, and spindle tuber. The unduly pointed ends of potato tubers indicate the last named disease. The first three, however, cannot be detected in the tuber. Many cases have occurred where attractive-looking seed stock has produced plants practically 100 per cent of which were affected with mosaic or curly dwarf, and consequently resulted in a very poor crop. These diseases are the most serious factors in getting good seed potatoes. The only way to avoid them is to make sure that they are absent in the fields where the seed was grown. These diseases can be detected only in the growing plants. Many growers who realize the loss caused by these diseases have learned to inspect during the preceding season the field from which they expect to purchase seed. Thus, selection of seed becomes a matter of selecting a healthy field in a section known to produce vigorous healthy potatoes. Such a practice, however, is not possible for all growers; neither are many growers sufficiently acquainted with the diseases to judge a field correctly. Hence we have had developed a system of seed certification, whereby the fields are inspected by a disinterested specialist, who certifies as to their health and seed-quality, insofar as these qualities can be judged.

As an illustration of the loss caused by mosaic disease, the results of a test carried out in 1923 in coöperation with the Agricultural Extension Service of Los Angeles County, are given in table 3. Several lots of White Rose potatoes were obtained from different growers and planted at Van Nuys.³ The per cent of plants affected by mosaic in each lot was recorded.

It will be seen that the lots having much mosaic produced low yields, while lots having little mosaic produced the highest yields.

³ In coöperation with Mr. A. J. Mueller.

There were evidently other factors affecting the results in this test, but the difference in highest and lowest yield demonstrates the effect of mosaic-infected seed on yields.

TABLE 3
RELATION OF PER CENT MOSAIC TO YIELD OF DIFFERENT STRAINS OF
WHITE ROSE POTATOES

Lot No.	Per cent Mosaic	Yield, pounds per acre
104	0	29,550
185	12.7	25,950
100	11.6	24,515
105	18.7	23,660
101	4.0	23,190
110	9.2	19,675
102	4.0	18,365
103	63.0	17,200
107	66.0	16,790

PREPARATION OF SEED FOR PLANTING

Many experiments have been made on the question of whole vs. cut seed-pieces. In general, it may be said that small tubers (from one to two ounces in weight) may be safely used for seed purposes if such small tubers come from healthy plants. It is dangerous to select small tubers for seed purposes from the bin unless one is sure that all the plants in the field where the crop is grown were free of virus diseases—otherwise the chances are that most of these tubers come from diseased plants and will produce a diseased progeny. An advantage of whole seed or “drop seed,” as it is usually called, is that it seldom decays without sprouting, as cut seed sometimes does, and hence gives better stands. Also the slight commercial value of the small tubers makes them a cheap source of seed. Disadvantages of whole seed are the difficulty of planting them with a machine, which generally necessitates hand planting; the danger of disease transmission; the slowness of germination if immature or the excessive number of sprouts produced if the seed has been in storage a long time. Drop seed, much used abroad, has never become popular in America. The point should be made here that small potatoes—one ounce in weight or over—need not be discriminated against if the stock is from healthy fields—hence seed stock does not have to be graded for size as does market stock. Tubers 1 to 2 ounces can be planted whole, from 2 to 4 ounces cut in half cross-wise, and larger tubers cut in the usual way.

As to size of seed piece, many experiments have been conducted, and many conflicting opinions are held. In deciding on the proper size to which the seed is to be cut, it is necessary to consider also the distance apart at which the seed is to be planted. If a wide spacing (14–18 inches) is to be used, the seed pieces should be relatively large—averaging 2 ounces each. If relatively close planting distance (10–12 inches) is to be used, then smaller seed pieces, averaging 1 to 1½ ounces, will serve best. Experiments have generally shown that yields increase with the amount of seed planted to the acre, whether the greater amount is used by cutting to larger size or by using small pieces planted closer together.

The larger the seed piece, the more stalks there will be, and consequently the greater number of tubers set in each hill. However, if there are too many stalks in a hill and consequently too many tubers are set, few of them will reach marketable size. Hence, the objection to seed pieces that are too large, aside from the greater cost. The optimum size for any given planting distance depends on the variety, the fertility of the soil, and whether or not the seed is fully out of the rest period when planted. Seed pieces from potatoes that are still in the dormant condition will usually produce only one or two stalks each; pieces from potatoes that have already begun to sprout will produce several; while pieces from potatoes that have been kept dormant in cold storage for several months beyond the end of their natural rest period will generally produce an excessive number. The practice of the best growers in California is to use from 8 to 10 sacks (110 pounds each) to the acre. This amount of seed will generally give best results if cut to 1 to 1½ ounce pieces and planted 11 to 12 inches apart in the row. In a record-breaking yield of 57,000 pounds an acre grown at Stockton in 1924, 22 sacks of seed were planted to the acre. Both plant-food and water must be supplied abundantly where very heavy seeding is practiced.

PLANTING

The date of planting depends upon the district where the crop is grown, the most profitable season of marketing, and the hazard from late frosts. It varies from November, in coastal districts like Colma and Carlsbad, to July in interior locations where a late crop is grown. Generally speaking, the earlier the planting date (without running undue risk of frost), the more satisfactory the development of the plants and of the crop, and the less the danger of injury from tuber moth. We have already seen how the tendency in recent years

in the Delta district is toward earlier planting and the use of earlier varieties than formerly, in order to mature and market a larger portion of the crop before heavy shipments from the Northwest commence in September. Though the time of planting is a factor that affects both the production and the value of a crop, it has to be determined largely by local conditions.

For planting a machine is generally used. Several types are on the market; namely, one-man machines, two-man machines, one-row planters, and two-row planters. The type of planter used depends on the preferences of the individual grower, the acreage he has to plant, and the amount of help available. More nearly perfect stands are likely to result where a two-man planter is used, but this is more expensive than the one-man or "automatic" type. Some of the large growers obtain good results with three of the one-row automatic dropping type of machines, hitched abreast and drawn by a tractor.

It is desirable to have enough moisture in the soil at planting time to germinate the seed promptly and to support its development until the plant is several inches high. Most California potatoes are grown in soils moistened by winter rains. It is occasionally necessary, however, to flood the land in preparation for the spring plantings and is always necessary before planting the fall crop. When natural moisture is to be held in the ground for planting rather late potatoes, it is necessary to give a shallow cultivation occasionally to keep down weeds that would otherwise sap the moisture from the soil very quickly. If the weeds are kept down, most soils will hold their moisture near enough to the surface for late spring planting.

Within a few days after planting, it is good practice to smooth down the planter ridges by cross-harrowing twice with the section harrow. This destroys many germinating weeds directly in the row. A second harrowing may be given just before the sprouts emerge, if development of weeds or the crusting of the surface by late rains warrants it. Usually as soon as the plants are up sufficiently to mark the rows, row cultivation with a two-row cultivator is begun. Sometimes, it is necessary to give the field a "blind" row cultivation before the sprouts emerge, if weeds are developing rapidly. In the early row cultivations, soil is thrown toward the plants slightly, but the main "hilling up" is deferred until the rows are furrowed for the first irrigation.

IRRIGATION PRACTICE

Almost every conceivable variation of irrigation practice is followed in various districts of California, ranging from culture under winter rainfall conditions at Colma through dry-farming summer culture in Marin County, to irrigation every $5\frac{1}{2}$ or 6 days in the Shafter district, and almost continuous irrigation through the main part of the growing season in the Sacramento-San Joaquin district. The amount of water required to grow a crop and the best frequency of irrigation vary so much with local climatic and soil conditions, that a general discussion is impossible.

The ideal condition is a uniformly ample supply of moisture throughout the season, especially from the time tubers are formed until shortly before harvest or maturity of the tops. The potato is particularly sensitive to irregularities in moisture supply during this period. Tuber formation begins when the plants are 5 or 6 inches high, and is completed by the time the flower buds are formed. Conditions during this period determine the number of tubers formed, or the "set." From the beginning of the flowering period until the plants are dead, the tubers grow at a regular rate, if uniformly favorable conditions exist. Hence conditions during this period determine the development of the tubers, especially as to size, smoothness, and shape. The rate at which potato plants exhaust moisture from the soil is proportional to their leaf area, hence the need for water is greater as the plants grow larger. Also, varieties characteristically having large vines with a large leaf area use more water than do those having a smaller foliage system. The use of water is further influenced by temperature and by humidity of the air—higher temperature and lower atmospheric humidity increase the transpiration rate. It is quite possible that large plants under mid-day conditions in summer may give off moisture faster than their roots take it up, even from a moist soil. This condition leads to incipient wilting and is apparently connected with several troubles that potatoes are subject to under irrigated conditions, such as knobby tubers, vegetative sprouts from half-grown tubers, heat necrosis, and internal browning.

In Utah, where the water requirements for potatoes are probably not as great as in central and southern California, Harris⁴ found that where water was applied once a week during the growing season, applications of 1 acre-inch at each application gave better results than $2\frac{1}{2}$, 5, or 7 inch applications. In a set of experiments designed

⁴ Harris, F. S., The irrigation of potatoes. Utah Expt. Station Bull. 157:1-20, 1917.

to find at what stage of development a single irrigation would be of most benefit to the crop if only one application could be made for the whole season, the best yields were secured by applying the water when the plants were in full bloom, rather than at earlier or later stages. The largest yield secured from any of the treatments tested was obtained by the application of one acre-inch each week. This required only 13 acre-inches for the season and served to emphasize the importance of regular moisture supply through the growing season.

Another point requiring careful consideration is the proper time to commence irrigating. Irrigating too early may favor the development of an overly large plant. Such over development may accentuate moisture troubles later in the season. A fair supply of moisture in the soil, however, during the tuberizing period—just before the flower buds form—is necessary to secure a good “set” of tubers. Allowing the plants to suffer for water after the tubers are already formed results in rough, ill-shaped tubers. Any very decided check from lack of water the latter part of the growing season, even for a short period, followed by late irrigation, is almost certain to result in knobby second growth and cracking of the nearly mature tubers by “growth cracks.” One rule is to delay the first irrigation until plants show a slower rate of growth indicated by darker green color of foliage, but have not yet reached the stage where there is even slight wilting during the midday period. Thereafter, irrigations should be frequent enough to keep the plants growing at a uniformly rapid rate. The total amount of water required by potatoes is not large if it is well distributed. Frequent irrigations appear to be most desirable for the development of both plant and tubers.

FERTILIZATION PRACTICE

In many districts it has been found necessary to give attention to soil fertility in potato production, through applications of animal manures or chemical fertilizers or by plowing under green manuring crops. However, only limited information exists as to the kinds of fertilizers needed in the different districts or as to amounts that will give profitable returns.

Some indication of the benefit of nitrogenous fertilizers for potatoes at Riverside, California, was obtained by W. M. Mertz.⁵ A summary of his results on plots given the same treatment for five suc-

⁵ Mertz, W. M., Green manure crops in southern California. California Expt. Sta. Bull. 292:1-32, 1918.

cessive years is given in table 4. However, only two crops of potatoes were grown in this period, the results for the two years being averaged in the table. The check plots in this experiment receiving "minerals only" were given applications of acid phosphate and potash salts.

TABLE 4

RESULTS WITH NITROGENOUS FERTILIZERS ON POTATOES AT RIVERSIDE

Treatment	Yield per acre lbs.	Per cent gain
Average of four plots receiving minerals only	9,732
Same plus 41 lbs. nitrogen per acre	9,982	2.6
Same plus 82 lbs. nitrogen per acre	12,256	26.0
Same plus 123 lbs. nitrogen per acre	11,504	18.3
Same plus 163 lbs. nitrogen per acre	13,103	34.8

The application of nitrogen giving the greatest gross increase in Mertz' experiment, 163 pounds to the acre, would be equivalent to an application of 815 pounds of sulfate of ammonia, more than is generally considered either safe or economical to apply.

Recently, a large number of experiments with commercial fertilizers on potatoes have been carried out by the Agricultural Extension Service in Los Angeles County, under the direction of L. C. Holmes and F. H. Ernst, in coöperation with potato growers in that county, and have demonstrated large increases in yield of potatoes. These experiments were conducted on a large scale under field conditions on a number of different kinds of soil, and show strikingly the value of nitrogenous fertilizers for potatoes in that section. A summary of the results for 1922 is given below.⁶ The different mixtures were all calculated to supply about the same amount of nitrogen to the acre, from 40 to 42 pounds.

	Per cent increase over checks
320 lbs. fish meal plus 80 lbs. sulfate of ammonia, per acre	67
500 lbs. cotton seed meal plus 80 lbs. sulfate of ammonia, per acre	61
500 lbs. fish meal alone, per acre	55
700 lbs. cotton seed meal alone, per acre	40
500 lbs. tankage alone, per acre	38

Average yield of 18 check plots receiving no fertilizer, 64 sacks per acre.

⁶ Data from L. C. Holmes, formerly Assistant Farm Advisor, Agricultural Extension Service, Los Angeles County.



Fig. 6.—Effect of nitrogenous fertilizer on growth of potatoes at El Monte. On right, no fertilizer; on left of tree row, sulfate of ammonia and fish meal was applied. (F. H. Ernst.)



Fig. 7.—Effect of nitrogenous fertilizers on yield of potatoes in Los Angeles County. Yield with sulfate of ammonia and fish meal was 141 sacks per acre, without fertilizers the yield was 104 sacks per acre. (F. H. Ernst.)

As to the source of nitrogen in potato fertilizers, rather quickly available materials are preferred. Sulfate of ammonia and fish meal used in combination seem to be most satisfactory. Nitrate of soda is not favorable because it tends to increase the alkalinity of the soil, and as it is easily soluble in water, may be leached away before it is fully utilized by plants. Phosphorus, another element generally used in complete fertilizers, has shown no significant increases in yield in the Los Angeles experiments, and potash likewise showed no increase on the heavier soils, especially where green manuring crops had been plowed under. However, on the lighter, more sandy soils, potassium gave some increase in yield. As to the form in which potassium is used, there seems to be little choice. Many experiments have been conducted to determine whether there was any difference in the effects produced by potassium chloride (muriate of potash) and potassium sulfate. No significant difference between results with these materials has been obtained, either in this country or in Europe.

The use of chemical fertilizers has also been carefully investigated by some of the large growers in the Delta district. The potatoes here are grown on muck soils, which are generally deficient in minerals. Applications of fertilizers carrying a high percentage of phosphorus and potash have therefore become the practice. A favorite fertilizer mixture has been the 0-8-10 formula. An 0-21-24 formula is also used, this being obtained by mixing equal quantities of triple acid phosphate and sulfate of potash. While muck soils contain a relatively large amount of nitrogen, it is mostly in a form unavailable to plants, hence, some growers have found it profitable to use a small percentage of nitrogen in their potato fertilizers. Where only a small amount of nitrogen is desirable, the 3-12-12 formula is recommended.

Many of the soils on which potatoes are grown, especially in the Shafter district and in southern California, are very deficient in organic matter and in nitrogen. One of the most economical methods of building up the soils in this respect is the use of winter-growing leguminous crops, plowing these under in early spring, prior to planting the potato crop. In a comparison of nine different winter-growing legumes at Riverside, Mertz found that purple vetch (*Vicia atropurpurea*) and bitter clover (*Melilotus indica*) were the most satisfactory. These plants rank high in ability to grow during cool weather and under poor moisture conditions. The purple vetch produced 20 tons of green manure to the acre, and was estimated to return 228 lbs. of nitrogen to the soil, while the *Melilotus* produced 13.7 tons of green manure and furnished 152 pounds of nitrogen to

the soil and increased the potato yield 54 per cent. As an illustration of the beneficial effects of plowing under winter legumes for potato production, the following summary from Mertz's results is given.

	Pounds per acre	Per cent increase
Average yield on green manured legume plots	13,588	39.5
Average yield on non-legume plots, nitrates and minerals	11,711	21.2
Average yield on non-legume plots, minerals only	9,732

It is seen that the plowing under of legumes increased yield more than did heavy application of nitrogen in commercial fertilizers. This is to be expected, for the green manure crops add much organic matter to the soil, improve its texture and aeration, and leave the soil in a more congenial condition for the development of potatoes. However, great as is the benefit from plowing under green manures, experiments in Los Angeles County show that additional nitrogen, in commercial fertilizers, can be applied with advantage for potato production.

The winter legumes should be planted in early fall; the more growth they make before the colder part of the winter, the sooner they can be plowed under in the spring, and the less do they exhaust the soil moisture which is needed not only for the prompt decay of the green manure itself but for the sprouting of the potatoes.

HARVESTING

The yield of marketable potatoes increases rapidly as the plants approach maturity, even increasing somewhat after the vines have turned yellow. Nevertheless, a considerable portion of the crop is harvested when only partially matured, because early potatoes bring better prices and because heat or tuber-moth may cause injury if the crop is allowed to grow until the vines die down. All of the crop in the extra-early districts, such as Colma and Carlsbad, is harvested when only partly grown, as "new potatoes," because of the favorable market conditions. Most of the spring crop in central and southern California is also harvested quite immature.

The skin on immature potatoes is very thin and is easily rubbed off. As the potatoes approach maturity, the skin becomes thicker, tougher and more firmly attached to the tuber. The advancement of this change in the coat of the tuber is important in determining when to start digging early potatoes. If harvested too immature, most of

the skin is knocked off in handling, sacking and loading. These "skinned" areas quickly turn black and are often the starting places for decay, or at least the potatoes are rendered very unsightly. Immature potatoes, as indicated by the ease with which the skin is rubbed off, are of very poor shipping and keeping qualities, especially when dug in warm weather. As the potatoes become more mature, the skin becomes thicker, and tougher, the potatoes stand handling better, and may be expected to reach the market in better condition.

INSECTS OF THE POTATO

Stalk Borer.—Occasionally the potato stalk borer causes some damage. The grower may recognize this insect in its larval stage, as a white or yellowish grub, from $\frac{3}{8}$ to $\frac{1}{2}$ inch in length, burrowing channels in the pith of the stalk. It pupates in the dead stalk where the adult beetle also hibernates, emerging in the spring about the time the new plants are coming up.⁷ A large percentage of the plants was destroyed by the insect in some fields at Stockton in July, 1924. No satisfactory control measure is known. Burning of the dead vines after the crop is harvested has been suggested, but would not be practicable on muck or peat soils unless special arrangements are made for extinguishing the fire.

Tuber-Moth.—This insect has been in California since the early days, having been first reported at San Francisco in 1856. It has gradually spread to all the important potato growing districts of the state and has become one of the chief difficulties with which the potato grower has to contend. The eggs are laid upon leaves and stem and in the eyes of exposed tubers in spring and summer, or upon the tubers before or at digging time. The larvae hatching from these eggs burrow through the tubers, starting at the eyes, where a little pile of black frass is noticeable if the larvae are within the tuber. Affected tubers are rendered unfit for market and frequently this injury is followed by decay. Further loss has been caused the grower of early potatoes by quarantines against shipments from tuber moth districts, put in effect by states of the Northwest, to which California ordinarily ships a considerable quantity of early potatoes. However, these states have been admitting potatoes, which are certified to be free of tuber moth by the California State Department of Agriculture. The recent development of a system of fumigation with carbon bisulfide under vacuum will further aid in marketing early potatoes in the Northwest.

⁷ Essig, E. O., *Injurious and beneficial insects of California*, pp. 303-305.

Control measures for tuber moth consist mainly in preventing the infestation of the tubers. The following recommendations⁸ have been made.

1. Clean culture—Destroy weeds and volunteer potatoes which harbor this insect.

2. Clean seed—Plant only seed known to be free from tuber moth infestation.

3. Deep planting—Potatoes planted 5 to 6 inches deep will be less affected.



Fig. 8.—Tuber moth injury to potatoes. On left, piles of black frass are noted at the eyes, where the larvae have bored into the tuber. On right, tunnels of the larvae within the tuber.

4. High ridging—After the tubers are set, the deeper they are covered by ridging the soil toward the plants, the less likely they are to be attacked.

5.—Do not allow the soil around the plants to crack open—High ridging and careful irrigation will largely prevent this. A successful practice has been to pass over the field with a light roller soon after the last irrigation to close the cracks in the ridges. As the plants are practically mature at this time, this treatment does not affect the yield seriously, but does prevent infestation of exposed tubers during the brief period intervening before the crop is dug.

6. Early harvesting—The larvae feed on the tops as long as they are green, and afterwards will make special efforts to get at the tubers.

⁸ Calif. State Dept. Agric., Spec. Pub. 24:1-6, 1922.

7. Never leave potatoes exposed over night as the moths fly and lay their eggs mostly at night, hence potatoes left in the field are likely to be covered with eggs, which will develop later in transit or in storage.

8. Never place potato vines on top of the sacks or lugs containing potatoes, for the larvae on the vines are likely to be transferred to the tubers.

9. Place potatoes under refrigeration as soon as possible if they are to be shipped. The low temperature of the refrigerator car checks the development of tuber moths that may be in the potatoes.

Aphids.—Several species of aphids (green plant lice) frequently attack potatoes in California. At times these insects are so numerous that the under sides of the leaves are literally incrustated with them, and the plants are thus greatly weakened. But usually, the attacks are not severe enough to cause obvious damage. However, the various species of aphids have been proved the principal means of spreading throughout the field such "virus" diseases as mosaic, curly dwarf, leaf roll, and spindle tuber. Hence, their control is especially important to the seed growers. Aphids feed on diseased plants, then migrate to adjoining healthy plants carrying infection with them. Plants infected in this way may not show it the same season, but the tubers grown on them will produce diseased plants the following year.

The various kinds of aphids attacking potatoes can be controlled by spraying with nicotine solutions. "Black Leaf 40," diluted 1 to 800 in water, is effective if carefully applied. Recently nicotine dusts have been used very effectively against aphids. Dusts containing 2 per cent of nicotine sulfate are effective. For application on a field scale, horse-drawn power dusters, equipped with a canvas trailer to hold the dust over the plants, have proved convenient. Potato plants should be watched closely during the early part of the season and control measures applied before the aphids become numerous.

Nematodes.—The garden nematode (*Heterodera radicicola*) or eel-worm is a soil-infesting microscopic animal of a lower order than the insects, and is the cause of a very common disease known as root knot on the roots of many plants. In potatoes, the tubers are chiefly affected, but characteristic galls have also been found on the fibrous feeding roots. Many acres of sandy and muck soils in California have become infested, but fortunately this nematode does not thrive in the heavier soils. Tubers infested with nematodes show numerous small raised galls over the surface, and when such potatoes are sliced,

small discolored channels are found just beneath the skin. The potatoes so affected are worthless for market or for seed purposes.

Nematodes have been widely distributed on affected nursery stock, vegetable plants, and seed potatoes. Once a field becomes infected, the insects are spread rapidly by farm animals, cultivating tools, and irrigation water. The only satisfactory method of freeing infected soils of nematodes is to grow immune crops for at least two years. Members of the grass family, particularly the cereals, and the Iron and Brabham varieties of cow peas, are suitable for this purpose. It is, of course, necessary to keep down weeds that the nematode might live on. Care should always be taken to see that seed potatoes, especially those brought in from other districts, are free of nematodes.

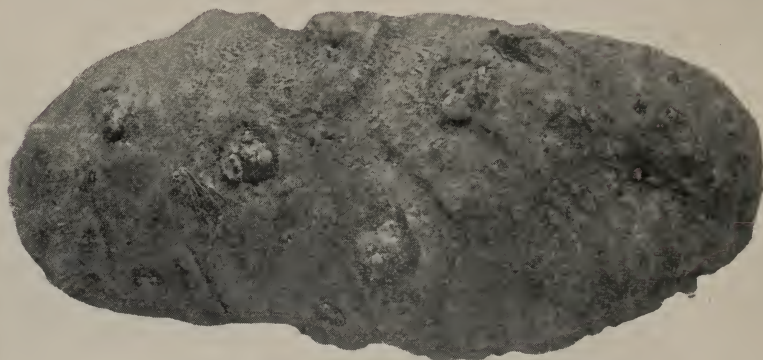


Fig. 9.—Tuber infested with Nematodes. The galls are especially prominent at the eyes of the tuber.

DISEASES

Various diseases take a considerable toll of the potato production in California, and the control or prevention of these diseases is one of the most important considerations in growing satisfactory crops and in getting good yields. The following table shows the average losses caused by the principal diseases in California as estimated by D. G. Milbrath of the State Department of Agriculture, for 1922 and 1923. Of course in some sections the loss from certain diseases is sometimes much greater than is indicated by the averages given in this list.

Per cent loss		Per cent loss	
Common scab	0.3	Fusarium root rot	0.5
Rhizoctonia	6.0	Fusarium dry rot of tuber	0.5
Wilt diseases.....	0.5	Mosaic (and curly dwarf)	5.0
Seed piece decay	2.0	Leaf roll	0.5
Leak of tuber	0.5	Internal browning of tuber	2.0
Jelly end rot	0.2	Heat necrosis of tuber	1.5
Early blight	1.0	Black heart of tuber	0.4
Late blight	0.1		

Fortunately, not all of these diseases are likely to occur in the same field or at the same time, for the conditions favoring some are unfavorable to others. Below is given a brief description of the principal diseases and their control, followed by a detailed description of general control measures.

Common Scab (Actinomyces sp.).—This disease is caused by a group of soil bacteria of very wide distribution, found even in virgin soils. The numbers of the organisms and the seriousness of the disease increase rapidly under condition of more or less continuous potato production. The disease, however, while widely distributed in California, has not been the cause of a very great loss. The tuber is the only portion of the plant attacked, the disease appearing first in small brownish spots that gradually enlarge into rough, corky patches, which may run together so that practically the whole surface of the tuber is covered. The scabs are usually elevated slightly around the margins, but may be sunken somewhat in the center. The exact appearance of scab seems to vary a good deal, probably according to the soil conditions where it occurs, or according to the particular species of the scab organism that happens to be present.

Scab is often introduced on seed tubers. This source of infection can be practically eliminated by dipping the seed in formaldehyde solution, but as this treatment is not so effective against other tuber borne diseases as corrosive sublimate, the latter is preferred. Seed treatment, however, is largely without effect if the soil is already infected; hence, some method of rendering the soil unfavorable for the development of the disease is needed. It has long been observed that scab is more serious where lime has been applied. Since lime makes the soil more alkaline, it was thought that the disease might be checked by making the soil more acid. This has been done very successfully in some eastern states, by the application of sulfur. The sulfur is oxidized by soil bacteria to sulfuric acid, which changes the soil reaction, either reducing the alkalinity or making it slightly acid,

depending on its original reaction. Fertilizers such as sulfate of ammonia, have the same effect. A series of plots at the University Farm at Davis were treated with various fertilizers in the spring of 1923 and again in 1924. Potatoes were grown both years on the same plots. The fertilizers were applied broadcast and then harrowed in just before planting. Table 5 gives the results of yield and the per cent of tubers from each plot infected with scab, for the spring of 1924, the White Rose variety, planted February 26, being used. Part of each plot was dug June 18 and the rest on July 2, when the plants were beginning to mature.

TABLE 5

EFFECT OF VARIOUS MATERIALS ON OCCURRENCE OF SCAB ON POTATOES

Treatment—	Yield in lbs. per acre		Per cent scabby potatoes (average)
	June 18	July 2	
Inoculated sulfur, 300 lbs. per acre	5,850	8,970	29.2
Commercial sulfur, 300 lbs. per acre.	6,260	9,670	27.2
Check, no treatment	5,730	8,440	47.0
Sulfate of ammonia, 225 lbs. per acre ..	6,360	9,870	34.8
Nitrate of soda, 300 lbs. per acre	6,500	9,540	47.6
Check, no treatment.....	6,370	9,440	51.4
Acid phosphate, 300 lbs. per acre	6,560	9,650	46.3
Sulfate of ammonia, 225 lbs. per acre }	7,140	9,470	27.1
Acid phosphate, 300 lbs. per acre			
Potassium chloride, 100 lbs. per acre }			

While these results do not reveal any very definite effect of the fertilizers upon yield of potatoes, they do indicate a marked effect on the prevalence of scab. Comparing the two check plots, with 47.0 and 51.4 per cent of scab respectively, to the two sulfur plots with 29.2 and 27.2 per cent of scab respectively, it is seen that both forms of sulfur considerably decreased the amount of scab and correspondingly increased the percentage of clean potatoes. It should be recalled, however, that these results were for the second year these plots had received the same treatment. The first year, two crops were grown; the spring crop, however, was a failure and no scab counts were made. The fall crop that year gave differences in scab infection similar to the above. On the other hand, two experiments carried out in Los Angeles County in 1922 showed no effect from application of sulfur for control of scab. Under conditions of severe soil infection application of sulfur, however, is likely to prove helpful, unless the soil is excessively alkaline.

Rhizoctonia (*Corticum vagum*).—This is probably the most destructive fungous disease of potatoes in California. Like scab, it is transmitted both on the surface of seed tubers and in the soil. Except where potatoes are grown continuously, or where they follow some other susceptible crop, soil infection is not so serious with *Rhizoctonia*; control, therefore, by seed treatment is more effective. Injury as a result of infections from the organism already in the soil, however, often causes serious loss even where treated seed is planted, especially where potatoes follow Lima beans, another host plant, in southern California.

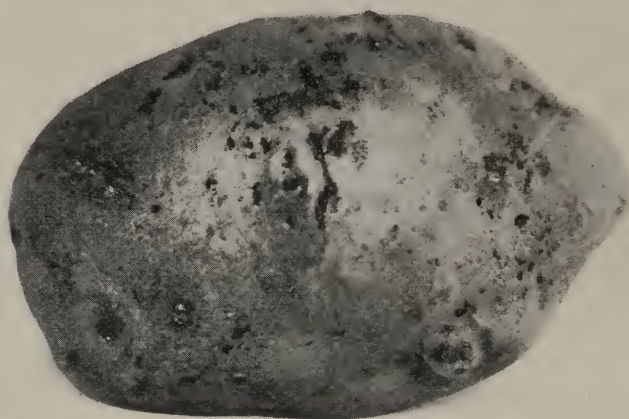


Fig. 10.—“Black Scurf,” the sclerotia or resting stage of *Rhizoctonia* on surface of the tuber.

The disease appears on the surface of the tuber as small, black specks, the sclerotia or resting state of the fungus. This stage does little harm in itself, but detracts somewhat from the appearance of the tubers. It is, however, the source of infection to the plants grown the following year from infected seed. When such seed is planted, the fungus starts growing and attacks the sprouts, leading to another phase of the disease, in which the direct loss is great, resulting in many missing hills in the potato field or in weak non-productive plants. Upon digging up the seed piece, it is found that the tip of the sprout has died before reaching the surface of the soil. A second sprout may be sent up from the first one and may die in the same way. Or the sprout may reach the surface and produce only weak, spindly plants, because of injury to the lower part of the stem. In this kind of attack, the disease is recognized as brown decayed areas

on the white underground stems. Plants may also be attacked later in the season. On the underground part of the stem are found superficial brownish areas, often entirely girdling the stem, sometimes accompanied by deep lengthwise cracks in the cortex. Plants attacked in this way may turn yellowish, the leaves become considerably rolled, and small greenish tubers appear in the axils of the leaves on the above-ground stem. Without showing such pronounced symptoms, the fungus may attack also the tuber-bearing stolons which branch out from the underground stem, and thus prevent tuber formation.

The *Rhizoctonia* fungus thrives best at relatively low temperatures and is most likely to attack potatoes planted in the cooler part of the year. This has led some growers to omit the precaution of treating the seed when planting a summer crop. It is advisable, however, to treat the seed no matter what season of the year it is planted, and regardless of whether or not the seed seems to be infected. It has been shown that seed, which to the eye appears to be free of *Rhizoctonia*, may have a considerable amount of disease in the resulting crop unless disinfected before planting.

Soaking the seed in corrosive sublimate solution (1-1000) for 1½ hours is the usual method of disinfecting seed for the prevention of this disease. Formaldehyde (in cold solution) is not effective against *Rhizoctonia*. Rotation of crops is also important in preventing this disease.

Wilts.—There are at least three organisms that cause a wilt disease of potatoes more or less generally in California, though seldom to any great extent. These are *Fusarium radiculicola*, *Fusarium oxysporum*, and *Verticillium albo-atrum*. The effects of these three diseases are so nearly alike that they cannot be distinguished in the field. The attacked plants wilt slowly and die, even after they have reached nearly their full size. The first two diseases at least are favored by high temperatures and other conditions unfavorable for the potato plant. If the lower part of the stems of plants attacked by wilt are split, it will be found that the woody portion is brown in color, in contrast to the greenish white of healthy stems. Many of the tubers produced by wilt-infected plants will also show a dark ring in the region of the vascular bundles just below the skin, if clipped at the stem end. However, there are other causes of similar darkening of this vascular ring; in fact, McKay⁹ in Oregon found that less than half of the tubers so affected contained wilt organisms, and on the other hand, many potatoes that showed no discoloration, did contain

⁹ McKay, M. B., Transmission of some wilt diseases in seed potatoes. Jour. Agric. Research, 21: 821-848, 1921.

the wilt organism. This shows that it is impossible to select wilt-free seed simply by discarding tubers showing internal discoloration.

There are three methods of infection: from the soil through the seed pieces; from the soil through the roots; and from the seed tuber itself when infected seed is planted. Rotation of crops, wherein potatoes are not grown more than once in four or five years on the same land will aid in reducing loss from wilt. As a general practice, it is best to discard all tubers that show any internal discoloration, so far as use of seed is concerned, but this by no means insures one against the occurrence of wilt in the resultant crop. Disinfection of the seed is of no avail against wilt, for the organism is within the tuber and so is not reached by the disinfectant. The only reliable means known for avoiding wilt is the use of seed from healthy plants only. Under practical conditions this means the removal of wilt-infected plants from the seed fields as soon as they occur. McKay has shown that the disease spreads from wilted plants to adjoining healthy plants rather quickly; hence, the need for frequent and prompt roguing of the seed fields. Growers of certified seed especially should be on the watch for wilted plants and remove them promptly. A single roguing toward the end of the growing season is of little use.

Stem-end Rot (Jelly-end Rot).—This is a type of decay that quite commonly attacks the stem end of long-tubered varieties. It takes several different forms and is said to be caused by several different organisms, principally different species of *Fusaria*. It is usually noted in the field at harvest time, especially if the crop is fully matured. Common forms of stem end rot show a dry, sunken, brownish, or black discolored condition for a short distance back from the stem end, or a soft, jelly-like, light brown colored rot extending an inch or more from the stem end. In either case, the remainder of the tuber appears sound and is separated by a definite boundary from the decayed area. The rot may or may not make further advances during storage.

In so far as stem-end rot is associated with the diseases that cause wilt, it can be controlled by the means suggested in the preceding section. However, some stem end rot occurs where the wilt diseases are not apparent. Doubtless some of the surface and stem end rots that occur after harvesting are caused by soil organisms that gain entrance to the tuber through the cuts and bruises resulting from rough handling.

Leak.—The leak disease, which occurs in potatoes dug and shipped during hot weather, has been a cause of some loss in the Delta district. It is caused by soil organisms that gain entrance through wounds made in digging the potatoes by hand, a practice formerly quite general in the Stockton district. The disease is not common in potatoes grown in newly reclaimed or burned over peat lands. Hawkins¹⁰ found that this was due to the absence from these soils of the rot-producing organisms. He concluded as a result of his investigations that sorting out all wounded potatoes (injured by



Fig. 11.—Plant on right shows mild infection of mosaic. Healthy plant on left.

digging forks and by breaking off knobby second growths) would insure the lot from damage by this disease. Fortunately, the disease is decreasing in prevalence because of the increasing use of machine diggers in the Delta district, and the planting of a type of potato less likely to produce knobby second growths than the Burbank, which formerly was grown exclusively in the Delta.

Mosaic.—This term is used to include what appears to be at least three distinct diseases, known as mild mosaic, leaf-rolling mosaic, and rugose mosaic, all having the characteristic symptoms of dwarfing the plant to a greater or less extent, mottling and wrinkling the leaves, and reducing the size of the tubers. Mosaic is one of the

¹⁰ Hawkins, L. A., Experiments in the control of potato leak, U. S. Dept. Agr., Bull. 577:1-5, 1917.

commonest and most threatening of diseases found in potatoes, not only in California but throughout the country. It has already been shown (p. 17) how the presence of mosaic diseases reduces the yield of infected stock. In fact, it is now thought that most, if not all of the troubles formerly attributed to degeneration and "running out" of seed stocks, are due to mosaic and related diseases.

Certain definite characteristics of the mosaic diseases should be clearly understood. While no micro-organism has been found as the cause of these diseases, still they are infectious and spread from plant to plant in the field, the chief agency for dissemination being the aphid or plant lice. These insects, after sucking juice from a diseased plant, may move to a healthy plant and infect it. No sign of such secondary infection may appear, but the tubers from such plants will produce diseased plants the following year. In this way, a lot of potatoes that has only a few mosaic plants one year may show almost complete infection the following year, if aphids have been numerous. While the disease is transmitted from year to year in the seed tubers, such infected tubers show no sign of the disease, and may, in fact, have the appearance of very fancy potatoes. Cases have been recorded where prize-winning lots from fairs or shows were planted the following year and gave almost 100 per cent infection of mosaic with correspondingly poor yields. Mosaic is likely also to be transmitted from year to year in volunteer potatoes which spring up from the culls left in the field at digging time. Other crop plants—tomatoes, tobacco, beans, and cantaloupes—have mosaic diseases, and it is possible that infection may be carried from one crop to another. Weeds, especially perennial or winter-growing, are likewise suspected of wintering over the disease.

There is no direct method of control for mosaic diseases, but dependence is placed in use of healthy seed stock. Since there is no sign of these diseases in the tuber, the only way to form any opinion as to the health of the seed is to examine the growing plants in the field the preceding season. To prevent the dissemination of these diseases in the seed-field, careful roguing out of diseased plants early in the season must be practiced, as well as the control of aphids, and elimination of volunteer potatoes and of weeds, in the neighborhood, that might carry the disease. It has been stated that it is useless to try to free a stock of these diseases if 15 to 20 per cent of the plants are affected. The efficiency of roguing is also limited by the grower's ability to recognize the disease, for under certain climatic conditions the plants may be affected without showing the symptoms clearly

enough to permit thorough roguing. Goss¹¹ found that temperatures above 70° tend to mask the symptoms of mosaic, while temperatures below 70° increase their visibility. Another disease, spindle tuber, has exactly the opposite temperature relations. Low moisture and intense sunlight also seem to mask the disease symptoms. This indicates that roguing may be more effectively done, and therefore more healthy and productive seed may be produced, in some sections than in others. It is further indicated that roguing early in the season, before hot weather sets in, will be more effective for the elimination



Fig. 12.—Plant affected with severe mosaic, or curly dwarf.

of mosaic than later roguing. Still another helpful practice in control of mosaic is indicated by Oortwijn Botjes,¹² who states that secondary infection, which takes place in the field during the growing season, advances down the stem slowly toward the tubers. Thus there is a possibility of obtaining disease-free seed by digging early, before the infection from aerial parts has reached the tubers. This probably explains in part at least the well known advantages of using immature seed.

Leaf Roll, Net Necrosis, Spindle Sprout.—Leaf roll is a disease of the virus type having many of the characteristics of mosaic, so far as transmission is concerned. Dwarfing and rigidity of the plant, and rolling of the leaves along the midrib, are its effects. Frequently

¹¹ Goss, R. W., Effect of environment on potato degeneration diseases. Nebr. Station Research Bull. 26:1-39, 1924.

¹² Oortwijn, Botjes, J. Tidschr. Plantenz, 29: 113-126, 1923. (Abst. in Bot. Abst., 13: 54, 1924.)

leaf roll plants produce tubers that show a definite necrosis when the end is clipped, and sometimes tubers from such plants produce only slender spindling sprouts. However, these symptoms do not always accompany leaf roll, and apparently can also occur from other causes. Leaf roll is a very serious disease in some parts of the country, but is not seen very often in California. On the other hand, a spindle sprout trouble accompanied by a necrosis of the seed tuber, was a very serious cause of loss in southern California in the spring of 1924. Many seed pieces did not sprout at all, others sent out little secondary tubers by the direct method, while still others produced fine spindling sprouts that never developed into normal plants. In some cases the stand of normal plants was only 25 to 50 per cent. This trouble apparently was not connected with the leaf-roll disease, but was thought to be traceable to injury of the seed tubers in the field the previous year, by a combination of high temperatures and lack of water while the crop was maturing. Investigations on the cause and nature of this trouble are under way, but meantime it seems advisable to use seed grown in the cooler, more humid sections, and, in the absence of rainfall, to continue irrigation of fields intended for seed purposes as late in the autumn as possible.

Internal Browning and Heat Necrosis.—These are diseases of the tuber that appear when the maturing crop is exposed to hot weather. Frequently a considerable portion of the larger tubers are affected, in the summer crop of the warmer sections of the state. Internal browning appears as streaks or isolated brown dead spots in the middle portion of the interior of the tuber.

Heat necrosis probably is similar in its nature and cause to internal browning. It differs from the latter in that the dead tissue consists of small pithy brown spots distributed throughout the interior of the tuber. The disease seems to be connected with periods of unusually hot weather accompanied by low humidity or lack of moisture in the soil. This combination of conditions may cause the vines to give off moisture faster than the roots can obtain it from the soil. It is most likely to occur on sandy soils, which do not hold much moisture and accordingly dry out rapidly. More frequent light irrigations under these conditions should be helpful in preventing the trouble. It may also be suggested, that when a crop is practically mature but cannot be harvested before internal browning is likely to occur, that the foliage of the plants be partly killed by spraying with some toxic material. A 1 per cent solution of sodium arsenite will kill potato tops more or less completely.



Fig. 13.—Two rows on right show perfect stand obtained from normal healthy seed. On the left the stand is poor, apparently due to injury of the seed the previous year by lack of water and high temperatures. (F. H. Ernst.)



Fig. 14.—On left, abnormal tuberization characteristic of the British Queen variety when grown in warm sections. On right, formation of vegetative sprouts from nearly mature tubers. This occurs on many varieties when moisture supply is irregular and temperatures very high as the crop matures.

GENERAL DISEASE CONTROL MEASURES

Seed Treatment.—Disinfection of the seed before planting is a necessary step in potato culture, aimed primarily at control of scab and Rhizoctonia. Three treatments are in use: cold formaldehyde, cold mercuric chlorid, and hot formaldehyde. The first mentioned has been abandoned because it is not effective against Rhizoctonia. The second is the standard method at present, although hot formaldehyde is giving promising results in the East.

For the standard treatment, a commercial grade of mercuric chlorid (corrosive sublimate) is used at the rate of 4 ounces to 30 gallons of water. It is convenient to use a stock solution prepared at the rate of 4 ounces to 1 gallon of water, which is added to 29 gallons of water in the dipping tank just before starting the seed treatment. As mercuric chlorid is practically insoluble in cold water, the usual recommendation is to prepare the stock solution with boiling hot water. However, it has been found that mercuric chlorid will dissolve much more rapidly in the presence of sodium chlorid or ammonium chlorid. The proper amount of mercuric chlorid should be weighed out, placed in a stone crock or wooden vessel with an equal quantity of common salt, and the warm water added. If four times as much salt is used, complete solution is obtained in cold water in two or three minutes. This saves some trouble in preparing the stock solution, and the presence of the salt does not affect the efficiency of the treatment.

The solution made by adding 1 gallon of stock solution to 29 gallons of water may be conveniently used in clean, tight wooden barrels of 50 to 60 gallons capacity. The barrels used for the treatment should be placed on a platform so that the solution can be drained off quickly at the end of each treatment and transferred to another barrel. A drain plug should be inserted in the bottom of each barrel for this purpose. Seed should be dumped from the sacks into the barrel, though it is sometimes treated in the sacks. This is objectionable, however, because the sacks absorb the mercuric chlorid from the solution very rapidly, thus weakening it and lessening its efficiency. In the past the usual recommendation has been to discard the solution after treating four successive lots. However, it is cheaper and more effective to maintain the strength of the same solution by adding one-half ounce of mercuric chlorid for every two sacks dipped, and sufficient water to bring the solution up to its original volume. If a stock solution (4 ounces mercuric chlorid to 1 gallon of water)

has been prepared, then 1 pint of this stock may be added to the dipping vat for every 2 sacks dipped.

As mercuric chlorid reacts with any sort of metal, only wooden, agateware, glass, or stoneware vessels should be used in preparing the solution. Dirt adhering to the surface of the potato also tends to weaken the solution at a rapid rate.

Potatoes should always be disinfected before they are cut. They should be left in the solution for $1\frac{1}{2}$ hours, as a shorter treatment is not effective.



Fig. 15.—Knobby second growths produced on partly developed tubers. Irregular moisture supply, especially lack of water during the middle of the season, causes this condition. It is not transmitted through the seed. Certain varieties are more subject to this trouble than others.

The hot formaldehyde has not yet been tried in California. A solution made by dissolving commercial formalin in water at the rate of 2 pounds (1 quart) to 30 gallons of water is used. The solution is heated to 122° F. and is kept between 118° and 122° F. while the seed potatoes are treated. The potatoes are immersed for exactly two minutes, and upon removal are dumped in piles, which are kept covered for one hour with a heavy canvas to hold in the fumes, thus making the treatment more effective. This method is well adapted to the treatment of large quantities of seed in a short time, but requires more skill and care to avoid injuring the potatoes than the mercuric chlorid method.

Crop Rotation.—Potatoes are likely to be more healthy and productive if grown in rotation with other crops. From three to five years between potato crops is advisable. Some of the worst diseases live over in the soil, and others are transmitted from year to year in the volunteer potatoes which spring up from the culls left in the field.

Control of Insects.—In some seasons, aphids are particularly numerous on potatoes, especially in the early part of the season. While they do direct damage by weakening the plants, they do even more damage by spreading mosaic and other virus diseases from plant to plant. The seed grower, especially, should be on the lookout for aphids in the potato fields, and be prepared to control them with nicotine dusts or nicotine sprays.

Use of Clean Healthy Seed.—This is the important factor in control of certain diseases. While any grower can produce good healthy seed by taking proper precautions, still it is more likely to be actually done by the seed specialist. Such potatoes are produced at greater expense than the usual market crop, but if they are actually freer from disease than ordinary stock, they are worth more for seed purposes.

PRODUCTION OF CERTIFIED SEED POTATOES

With the increasing prevalence and number of diseases of potatoes, and the greater risk in purchasing seed stocks about which nothing was known by the purchaser, has come the realization that the production of satisfactory seed requires special skill and care. Consequently, there has been developed in California and other seed growing states during the past ten years a system of seed certification. To accomplish this, fields entered for certification are inspected twice during the growing season and once after harvest by a representative of the State Department of Agriculture to determine as accurately as possible whether the potatoes come up to the required standards for certified seed. The principal requirements are:

1. True to name. Not more than 5 per cent varietal mixture allowed at first inspection.
2. Of a type true for the variety.
3. Freedom from diseases. Not more than 10 per cent diseased plants and not more than 5 per cent of any one group—mosaic, leaf-roll, wilt and blackleg, and Rhizoctonia.

The first inspection should be made about blossoming time, at which stage it is easiest to detect varietal mixtures. Afterwards the grower is supposed to rogue out all off-type and diseased plants. At

a second inspection, later in the season, the permissible number of diseased plant is much smaller. Seed passing all inspections is sold under official certification tag.



Fig. 16.—“Witch’s Broom,” a disease characterized by excessive number of slender stalks, and production of few or no tubers. Such plants should be rogued from the seed fields.

Certified seed has in general justified the extra trouble and expense in producing it. Naturally seed buyers are interested in knowing whether, aside from all theoretical considerations, certified seed actually yields more than common stock. In Missouri, where average yields from several certified and uncertified strains were taken, there was a gain of 20 bushels an acre for the certified seed. In Connecticut certified seed averaged an increase of 62 bushels to the acre. In Michigan, where 2,100 acres were planted with certified seed in 1923 the average increase over plantings with uncertified seed was 78 bushels an acre. These illustrations indicate that the principles on which seed potatoes are certified have a firm foundation. It is, nevertheless, true that some lots of certified seed have given unsatisfactory results. Apparently, such cases can be traced to two causes (aside from fraud): either the field from which the seed came was attacked by aphids, which spread such diseases as mosaic, or climatic conditions were such that mosaic-infected plants could not be recognized and, accordingly, were not rogued out.

Careful roguing is absolutely necessary in order to produce high grade potatoes. The fields should be rogued not once but a number of times during the season. Many certified seed growers have made the mistake of waiting until the plants are nearly mature before roguing, overlooking the fact that plants infected with mosaic were thus allowed a long period to transmit the disease to their healthy neighbors. Early roguing will reduce the number of plants to be rogued out, and, to a still greater extent, will reduce the amount of disease in the next year's crop.

In making the first roguing, it is convenient to carry a small pail of kerosene, in which to dip diseased plants as they are dug. In later roguings when the plants are larger, the rogued out plants should be placed in a sack, taken from the field, and destroyed, the object being to destroy any aphids that might be on these diseased plants and which would certainly infect others if allowed to escape. In roguing, the entire plant should be removed, including the stem, seed piece, and tubers, if any. Diseases like mosaic permeate all parts of the plant, and if any portion is left in the soil, new infections may result.

About 600,000 sacks of seed are required to plant the potato acreage in California each year. About 60,000 sacks of certified seed were produced in 1923; hence it is seen that there is still plenty of room for expansion in production of certified seed.